Development and characterization of meter scale gas jets suitable for ≥10 GeV electron acceleration in HOFI plasma channels

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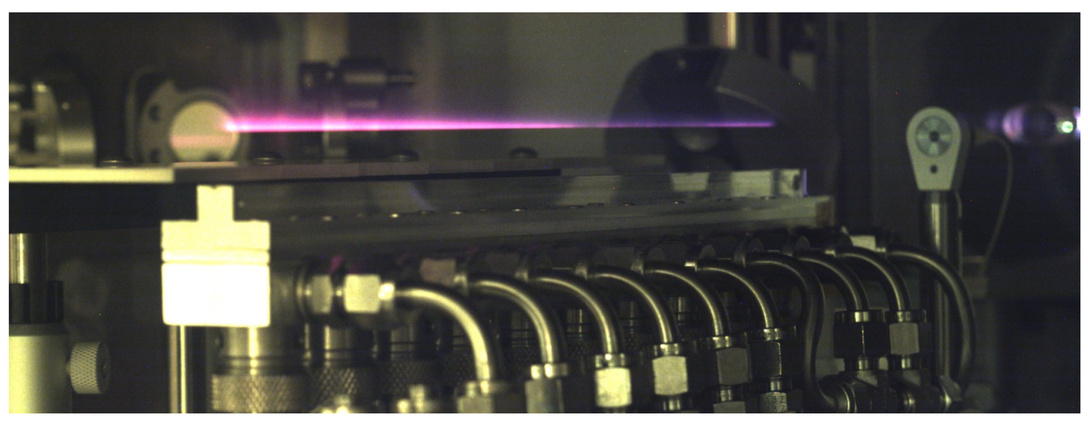
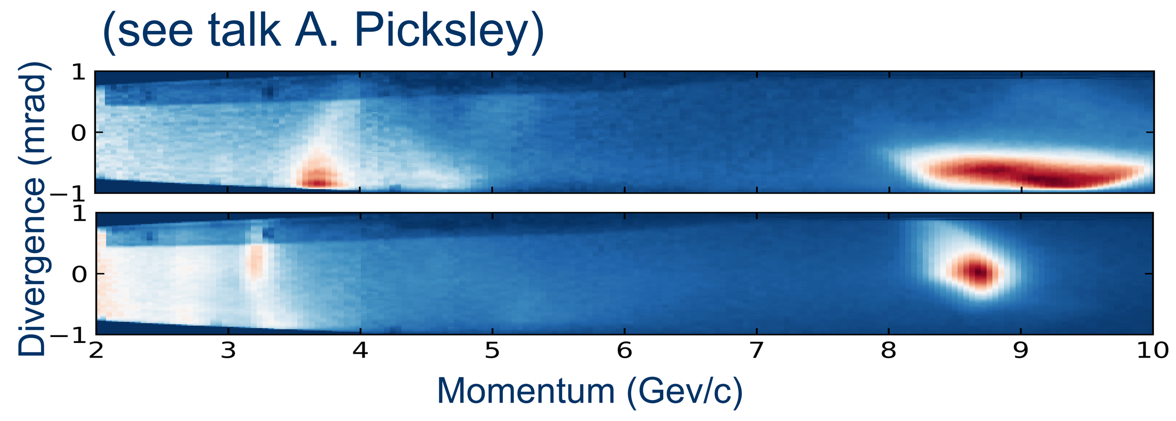
Background

- Generating multi-GeV beams is possible with PW-class lasers [1] but requires an accelerator many Raleigh lengths long
- Plasma waveguides can combat diffraction of the drive laser
- Hydrodynamic Optical Field Ionization (HOFI) channels are particularly suitable waveguides since they are free-standing and provide an appropriate plasma density gradient [2-5]



- HOFI channels from 30cm gas jet enabled generation of quasimonoenergetic electron beams up to 9 GeV, with energy tails up to 10.2 GeV (see talk A. Picksley)

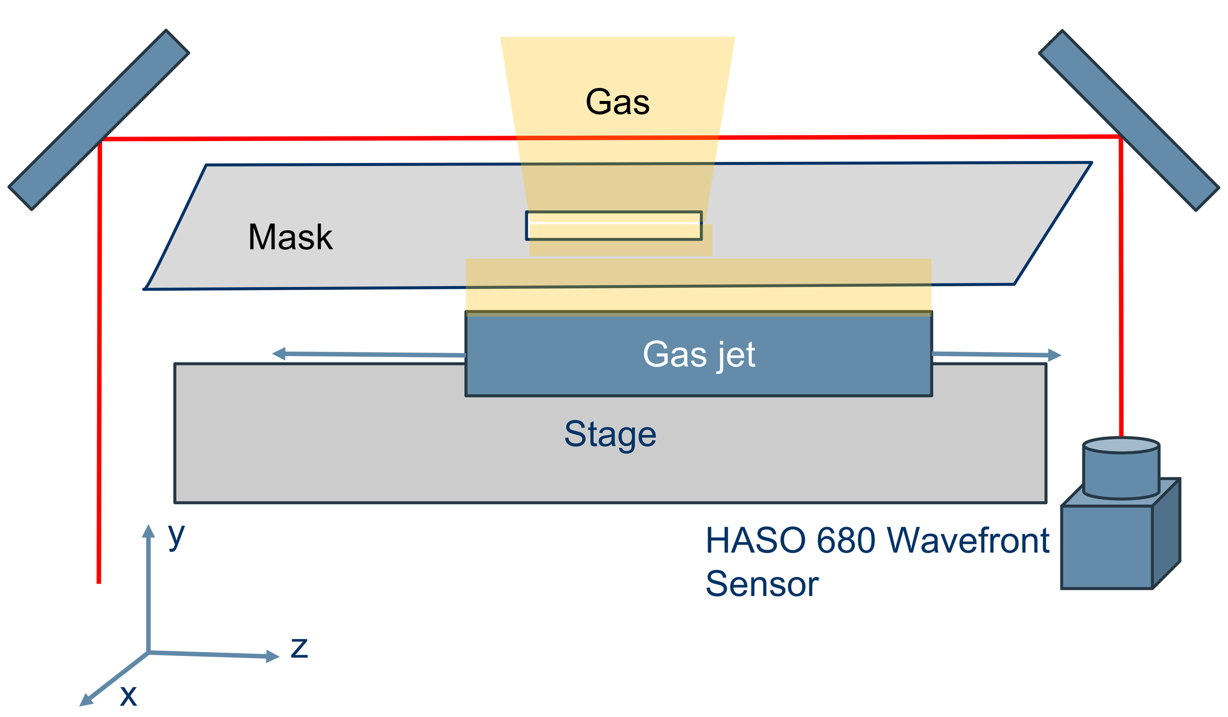


Motivation

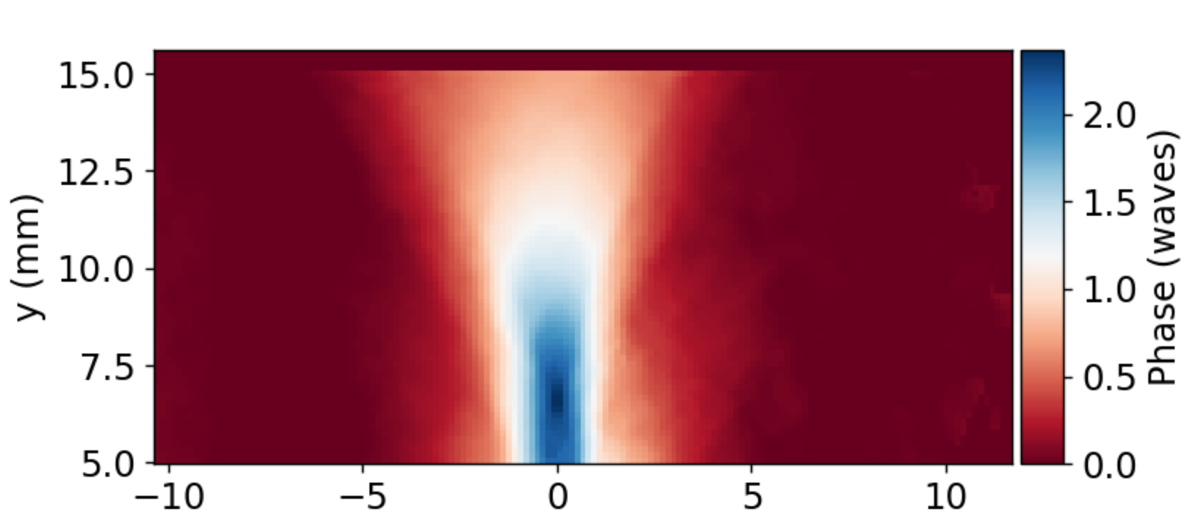
- A gas jet ~30 cm long and a **plasma electron** density of ~10^{17} cm^{-3} meets the conditions for a 10 GeV electron beam [6]
- We would like to measure gas density without a drive laser to test gas jets before high power campaigns
- We would like to measure the uniformity of the gas jet used in our HOFI channel campaigns

Gas Jet Requirements	Measurement Challenges
Molecular density of ≥ 5 x 10^{17} cm^{-3} since density drops by factor of ~10 during HOFI channel formation	Transverse interferometry is challenging due to aspect ratio of gas jet
Uniform gas density along length of jet to probe physics of uniform LPA stages	Longitudinal interferometry does not provide density distribution along gas jet length
Future work envisages tapered plasma channels via controllable gas density profile [7,8]	Low density (required for meter scale HOFI channels) results in lower signal-to-noise

Measuring the gas density profile of meter-scale gas jets

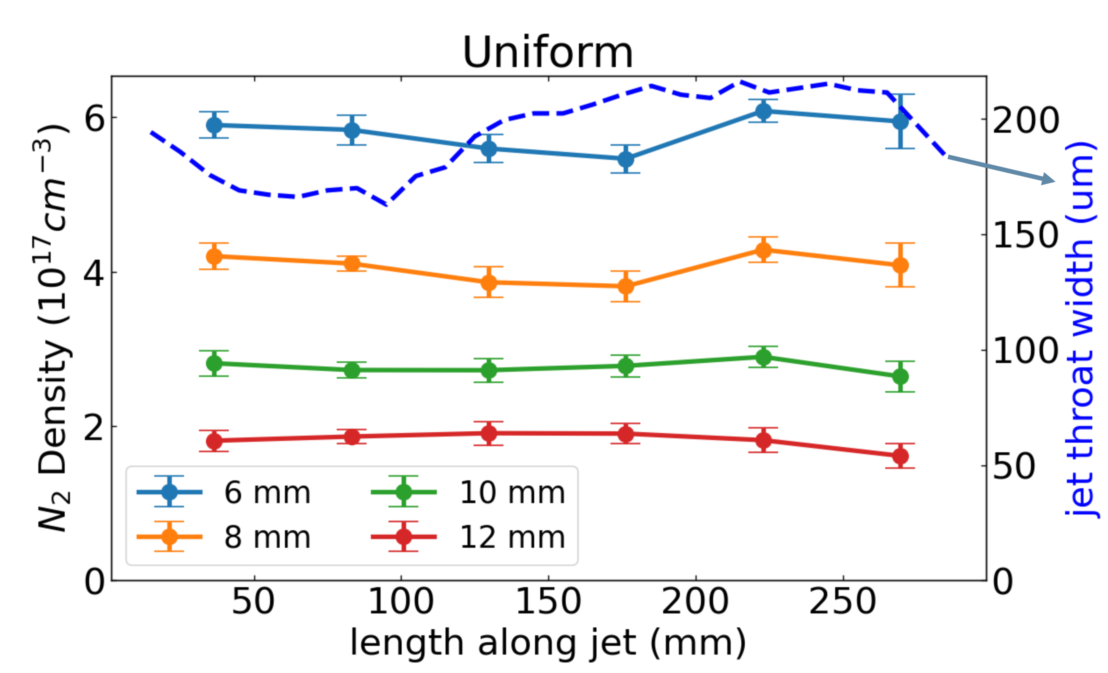


- A thin metal plate with a small (~few cm's) hole is used as a mask to only allow gas flow above a specific part of the gas jet
- By blocking most of the gas flow with the mask, the longitudinal gas density profile can be measured
- By measuring the phase difference between gas and vacuum, the density of the gas can be determined

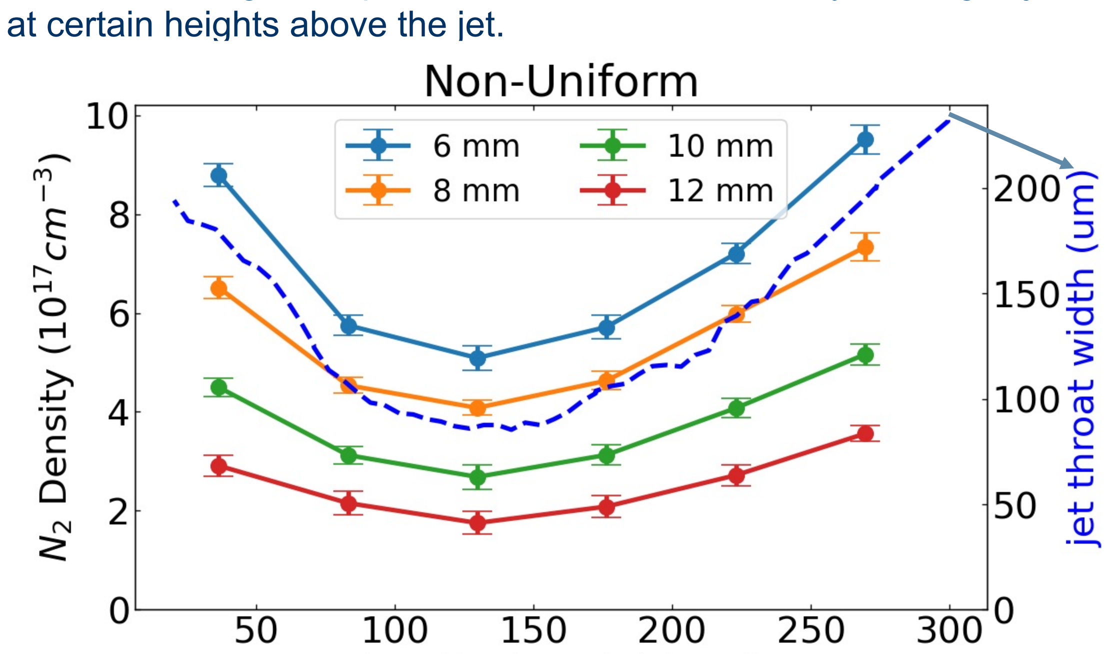


Raw phase data of gas density from a 30cm long jet. Y = 0 is at the height of the gas jet. X = 0 is at the center of the gas jet.

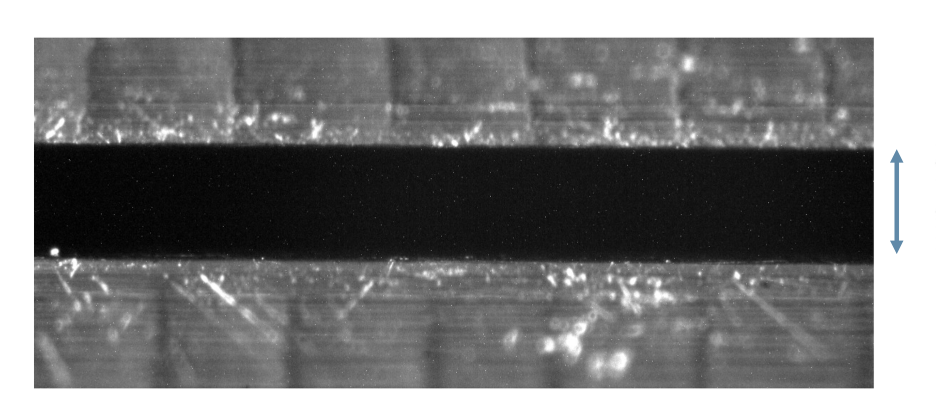
A path towards controllable density gas jets



Distances in legend represents the maximum density of the gas jet at certain heights above the jet.



- We found a strong correlation between gas jet throat width and gas density
- A uniform gas density was achieved for a 30 cm gas jet, which will allow us to study the physics of a uniform LPA



Microscope image of gas jet throat

- Leveraging throat width variation allows for tapered gas jets
- Tapering can prevent dephasing and increase electron energy [7,8]
- First attempt demonstrated control over longitudinal density profile

Conclusion and future work

- **We have developed a novel drive laser free setup for characterization of meter-scale gas jets suitable for ≥10 GeV electron beam LPAs.**
- **We demonstrated control over the longitudinal density profile, paving the way for experiments studying tapered plasma channels**
- Manufacturing an adjustable slit width gas jet optimized for BELLA PW parameters could increase electron energy and enable tapering studies

References

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